Development of a Vertically Profiling, High-Resolution, Digital Still Camera System

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LONG-TERM GOALS

Our scientific goal is to develop an improved capability for mapping the fine-scale horizontal and vertical distributions of mesozooplankton and other comparably sized particles in the oceans. Mapping of organisms in relation to environmental factors will help to understand the processes that lead to fine-scale patchiness. In-order to collect such biological and physical data, we require a system capable of quantifying zooplankton distributions and abundances on appropriate scales. This project is designed to develop a profiling instrument capable of collecting high-resolution images of zooplankton and other particles in the water column and environmental data on comparable spatial and temporal scales.

OBJECTIVES

1) To interface a high-resolution digital still camera, structured light source and environmental sensors with a surface control and acquisition computer;

2) To develop a graphical software interface to control the instrument; and

3) To evaluate the size distribution and abundance data generated by the profiling instrument in relation to a conventional multi-net (e.g. MOCNESS) system.

APPROACH

Our zooplankton visualization and imaging system (ZOOVIS) (Fig. 1) consists of a 2048 x 2048 pixel digital camera and a structured light strobe coupled to a CTD equipped with conductivity, temperature, pressure, optical transmittance, and fluorescence sensors. A fiber-optic interface on the camera provides the necessary bandwidth to transmit each 8 Mb digital image to the surface at image acquisition rates to

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1.5 Hz. The underwater unit is connected to the surface via an electro-optical oceanographic cable. Data from the camera and sensors and command and control flow bi-directionally via single-mode optical fibers while power is transmitted to the underwater unit via copper conductors. A surface winch equipped with a level-wind unit and an electro-optical slip-ring assembly controls payout and haulback of the underwater unit. Command and control are from a Pentium II PC running Windows NT.

Mark Benfield, with assistance from Richard Shaw, is supervising the overall testing and development of the system while Chris Schwehm is the project's electrical engineer. Chris has worked directly with engineers at PixelVision Inc., and Nbase/Xyplex to develop the fiber-optic network used in our system. We have also received cooperation from Oceaneering Inc. who have assisted us with all our fiber-optic connections between the cable, slip-ring assembly and surface telemetry hardware.

ZOOVIS has been assembled and bench top laboratory testing at LSU has been completed. This testing quantified the system resolution, depth of field and image volume under various combinations of focal length, aperture and target distance. Imaging of live zooplankton has been conducted to evaluate the performance of the system using realistic targets. Initial data indicate that the system meets performance expectations. ZOOVIS is capable of imaging the contents of a large volume of water (up to 600 ml) at distances of 30-70 cm from the camera. Zooplankton ranging in size from 2-30 mm of a variety of opacities (opaque to almost completely transparent) were clearly visible in our test images. Field trials of the system will be undertaken during a research cruise on the CSS Vector during an ONR-funded project in Knight Inlet, Vancouver Island, Canada.

WORK COMPLETED

Funding for this project was available in July, 1998 and the project is in its final year. Work during the first year of the project focused on developing specifications for the ZOOVIS components and securing the system components. During the second year we conducted desktop assembly and system testing. During the past year, we have packaged the system in pressure housings, mated the system to our cable and winch, and worked to develop a command and control software interface. We are developing an image processing capability based on the Matrox MIL software to semi-automatically extract and store regions of interest from within each ZOOVIS image. The underwater components of ZOOVIS consist of four systems: telemetry, camera, strobe and the CTD. A trackpoint-compatible multibeacon is also present to facilitate recovery in the event the instrument package is lost. The surface components consist of a winch, fiber-optic telemetry hardware and a surface PC. All components are illustrated in Figure 1.

<u>Telemetry Housing</u>
Power (120 VAC) is provided to the telemetry pressure housing from the surface via the oceanographic cable. A power supply within the telemetry can then provides the DC voltages required to power the various system components. The telemetry housing also contains a single-mode to multi-mode converter and optical multiplexor; a 100base SX/FX converter module; a single board Pentium class PC equipped with 128MB ram, a 1GB microdrive and a single PCI slot mounting the Lynx camera acquisition card; and the camera power supply module. Fiber-optic data and command/control signals are sent to the camera housing via a pair of multi-mode fibers and a 20-conductor cable. Power for the strobe is sent to the camera housing where it picks up the synch signal from the camera before being routed to the strobe. Data from the CTD enters the PC via the RS232 port. An optional 4-pin connector will permit additional sensors to be added at a later time.

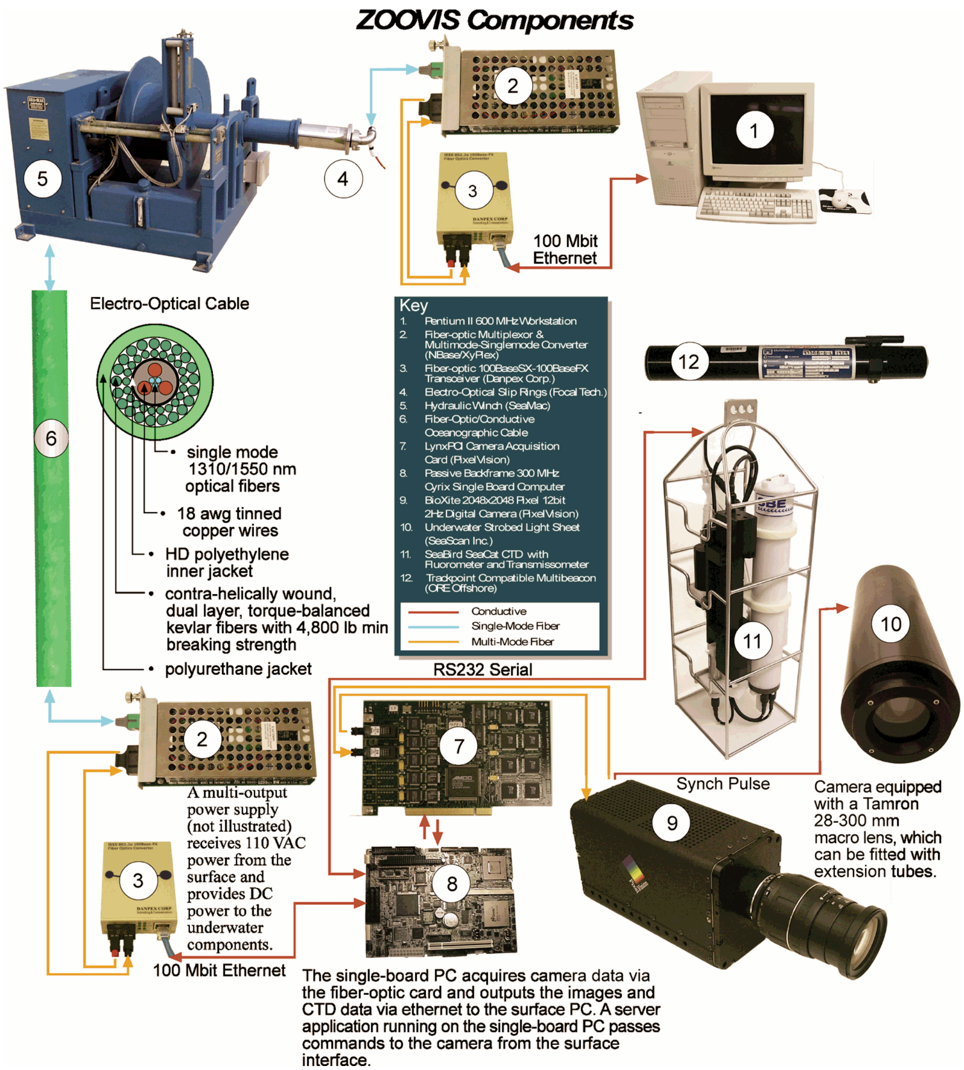

Figure 1. Primary surface and underwater components of the ZOOVIS digital camera system.

Digital Camera

The core of ZOOVIS is a 4.19 megapixel digital camera (PixelVision BioXite 2K) capable of providing 12 bit monochrome images (4096 levels of gray) at 2 Hz (Fig. 1). The camera is equipped with a fast zoom lens (Tamron 28-105 mm f2.8) with optional teleconverters for higher magnifications. The camera is equipped with a multi-mode fiber-optic input (command/control) and output (RS422 serial data) interface. The camera resides in a pressure housing fitted with a clear optical end port.

Structured Light Strobe

In order to eliminate the need to develop software to detect and reject out-of-focus targets, we opted to use a structured light source. By setting the depth of field of the lens to a range slightly greater than the width of the light sheet and centering the light sheet on the depth of field, all targets that are illuminated will be focused objects. Our strobe is a custom-built system designed by Seascan Inc. that produces a collimated, 20 µsec light pulse with a width that expands from 7 cm and a thickness of 3 cm. This will permit us to photograph volumes of up to approximately 600 ml while maintaining a pixel density of 145 pixels cm^{-1}.

CTD

Our CTD is a SeaBird Electronics Model SBE19 equipped with a fluorometer and transmissometer.

Electro-Optical Cable, Winch and Slip-Ring Assembly

ZOOVIS is connected to the surface via a 300 m length of electro-optical cable manufactured by Falmat Inc. The cable consists of three single-mode fibers and three shielded copper conductors surrounded by two contra-helically-wrapped Kevlar strength members wrapped in a polyurethane jacket. A Sea-Mac Model 210 electro-hydraulic winch equipped electro-optical slip rings (Focal Technologies) is capable of paying out and hauling ZOOVIS at up to 1 m/s.

RESULTS

Design, construction, and bench-top testing of the system have been completed. An operational prototype is in the final stages of assembly. Pressure testing to 51 atm has been completed on all pressure housings and components have been mounted on chassis and fitted inside pressure housings. The cable has been terminated, mated to the winch and the slip-ring assembly. An aluminum frame, which will hold all underwater components has been fabricated and will shortly be assembled.

We set out to design a system that could image a large volume of water while retaining sufficient resolution to identify small targets. Our results to date indicate that ZOOVIS is capable of meeting this performance goal. Images of relatively large volumes of water (300-600 ml) retain sufficient detail to allow recognition of small and large targets. Tests of the system using live zooplankton suspended in transparent tissue culture flasks that were immersed in a large aquarium indicate that the system can image relatively transparent organisms such as ctenophores and stomatopod larvae within a large volume of water as well as organisms in the 1-2mm range. The detail of such images is sufficiently high to permit identification and measurement.

We have a functional software interface to control ZOOVIS and monitor telemetry from the environmental sensors and winch. This surface control interface sends commands to a server application running on the underwater PC. We have hired a computer science undergraduate student who will develop an image processing application to locate and extract regions of interest from ZOOVIS images.

An invited paper "ZOOVIS: A high-resolution digital still camera system for measurement of fine-scale zooplankton distributions, by M.C. Benfield, C.J. Schwehm, R. Fredericks, and S.F. Keenan" describing the system will be part of a book titled: "Dealing with scales in aquatic ecology: measurements, analysis, and simulation" edited by the CRC Press. This book is scheduled for publication in 2002.

IMPACT/APPLICATIONS

This study will yield an instrument capable of imaging zooplankton-sized particles in waters to depths of 250 m while simultaneously collecting data on bio-physical parameters at comparable spatial scales. By coupling a high-resolution camera capable of sampling at up to 1.5 Hz, with a flexible zoom lens, we will be able to adjust the image volume for specific applications and different target size ranges. ZOOVIS will fill a niche between towed optical systems such as the VPR and moored systems such as the autonomous vertically profiling plankton observatory. ZOOVIS will be a shipboard instrument capable of rapidly collecting vertical profiles within surveyed areas. Horizontal distances between casts will be controlled by the user and scaled to match the patch structure of features of interest. Interpolation between casts within depth strata will provide a mechanism for volumetrically rendering

the distributions of taxa and environmental parameters. Applications include, but are not limited to: zooplankton surveys, ground-truthing of high-frequency acoustic backscatter profiles, and determination of the distribution and size structure of biotic and abiotic particles in the oceans.

TRANSITIONS

ZOOVIS was featured at the Louisiana Sea Grant Ocean Commotion on October 12, 2000. This one-day, annual event is designed to expose K-12 students to marine science. Students were able to use ZOOVIS to estimate the abundance of fishes in a tank based on densities from individual images.

ZOOVIS will be used in November 2001 for ground-truthing acoustic data in a collaborative ONR-funded project involving the Institute of Ocean Sciences, Canada and LSU. This study will examine the relationship between steep topographic features and zooplankton distributions. The use of a profiling instrument such as ZOOVIS is well suited to surveys around abrupt vertical relief. This cruise will provide an opportunity to compare ZOOVIS estimates of zooplankton density and multi-net samples.

We anticipate using ZOOVIS with Dr. Timothy Cowles (Oregon State University) in a sampling program OSU's Slow-Drop optical package off the Oregon coast during the Spring of 2002. Other future applications of ZOOVIS include a collaboration with Dr. Amatzia Genin, who has invited us to use ZOOVIS to monitor zooplankton flux across a coral reef off Eilat, Israel during 2003. In that application, we would moor ZOOVIS over the reef and run the cable directly to a shore-side laboratory. We have also discussed the potential utility of ZOOVIS mounted on an ROV within the proposed Pilot Census of Marine Life in the Gulf of Maine. To that end, meetings with colleagues at Oceaneering Inc. have included discussions of ways to reduce the size of the next generation system and interface it with an ROV.

RELATED PROJECTS

Our instrument will provide data on the spatial variation of zooplankton abundance and the size distributions of small particles on vertical scales of less than one meter, and horizontal scales of tens to thousands of meters. Such data are an essential for ground-truthing acoustics data and constraining the estimation of biomass from multi-frequency acoustic backscatter data. One of the PI's (Benfield) is currently analyzing data from an ONR-funded vehicle (BIOMAPER II) in the Gulf of Maine. In that study, zooplankton data were provided by a VPR and a MOCNESS. We have shown that optical data may be used to extract biomass data from acoustics (Benfield et al. 1998). With ZOOVIS, we will have a comparable ground-truthing capability for acoustic surveys including structurally complex areas where the use of towed instruments may be problematic. Insights gained from comparisons of the patterns of zooplankton distributions in the shelf waters off New England, the Gulf of Mexico, and North Pacific will help us to understand how zooplankton distributions and physical factors are related in coastal waters. Given the Navy's focus on littoral operations, this information will be useful for understanding and predicting spatial variation of sound-scattering organisms. Finally, high-resolution images from ZOOVIS will also be used in an ONR-funded collaborative project between BAE Systems and LSU. That study is designed to produce improved acoustical scattering models of zooplankton derived from high-resolution digitizations of actual animal silhouettes. We plan to use ZOOVIS images of larger zooplanktors as sources of digitized silhouettes.

REFERENCES

Benfield, M.C., P.H. Wiebe, T.K. Stanton, C.S. Davis, S.M. Gallager and C.H. Greene. 1998. Estimating the spatial distribution of zooplankton biomass by combining Video Plankton Recorder and single-frequency acoustic data. *Deep-Sea Research Part II,* 45: 1175–1199.

Benfield, M.C. and C. Schwehm. 2001. ZOOVIS: A high resolution digital camera system for quantifying zooplankton abundance and environmental data. Poster presented at the ASLO Aquatic Sciences Meeting, Albuquerque, NM, February 2001.